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The Winter Anomaly of the Night-to-Day Ratio of Ozone in the Middle to Upper Mesosphere in Middle Latitudes — A Comparison Between Measurements and Model Calculations

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Long-term ozone measurements by means of the microwave technique in middle latitudes atLindau, Germany (51.660 N, 10.130 E) over seven years showed that the night-to-day ratio(NDR) is markedly increased in the middle mesosphere during the winter season compared withthe ratio in summer. The anomaly is strongest pronounced in the domain between 65 and 75 km. This ratio is more than twice as large as during the summer season. The mean ratios at discretealtitude levels display an annual asymmetry with largest values before winter solstice. The NDRis modulated by variations of planetary time scale reminding of the well-known winter anomalyof the plasma parameter of the D-region. Model calculations on the basis of our new 3D-modelLIMA (Leibniz-Institute Middle Atmosphere model) for the selected year 2001 agree, inessence, with the observations although in some details noticeable differences occur. The strongsuperimposed variations of planetary time scale (some days to some weeks) point to dynamicalprocesses. Especially, the planetary wave activity and the occurrence of sudden stratosphericwarmings changing the temperature and the wind system but also the transport of long-livedconstituents such as water vapor are the cause for these variations. A remarkable influence onthe anomaly also has the photochemical Doppler effect introduced by Sonnemann in 2001. According to model calculations under the condition of the wintry prevailing zonal west windsystem, the nighttime values of ozone increase by more than 70 % and the daytime valuesdecrease slightly just in that region of the enhanced NDRs if comparing the behavior with thecase of zero zonal wind. The reason consists in the fact that the photochemical system of themesosphere is an enforced nonlinear chemical oscillator driven by the diurnally periodic solarinsolation able to produce chemical resonances. The period of the insolation for a moving airparcel declines up to 8 hours at the maximum of the strong mesospheric winter jet between 60and 70 km in middle latitudes because the air moves with the rotation of the Earth there. Particularly, the relations during sunset influence the level of the nighttime ozone. We presentboth observations and model calculations and discuss them in terms of chemistry and dynamics.